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ABSTRACT

Three articles in this newsletter describe investigative laboratory programs; two in marine or coastal biology (Hopkins Marine Station and the Bahamas field station of Earlham College), and the other a botany course at Colorado College. In all cases undergraduate students are expected to plan and conduct biological research, after being presented with sufficient content work to provide a meaningful background for their own original research. The form of this initial instruction varies between the three programs described, with Colorado College providing instructional packages which students may take at their own pace, and the other two including formal lectures or seminars. The newsletter also contains reviews of two books concerned with the interface between chemistry and biology, a report of a CUEBS Minicourse on Modules, notes on visual aids, and comments on mathematics for biologists. (AL)

CUEBS

COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES

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THE LABORATORY AS AN INVESTIGATIVE OPPORTUNITY

This issue of **CUEBS News** adds considerably to the developing literature on the investigative laboratory in our newsletter and elsewhere. The first article, by John Thornton, describes the marine biology program at Hopkins Marine Station, which is under the direction of Donald Abbott. The second article, by Louis Wilcox, also deals with a marine biology program, this one in the Bahamas. These applications of the investigative laboratory will be of particular interest to both field- and organism-oriented teachers. Jack Carter's article is directed to introductory level plant science; in addition to "inside" study, there is a component of field investigations as well.

THE EDITOR

AN INVESTIGATIVE LABORATORY PROGRAM IN MARINE BIOLOGY

John W. Thornton
CUEBS Staff Biologist

The term Investigative Laboratory has been used by CUEBS to designate courses in which students are carefully prepared to select and handle individual research problems and then freed from rigid schedules to pursue investigations on their own.[1] The general concept of an investigative laboratory has been applied in a variety of specific circumstances ranging from an introductory course for nonmajors in a 2-year community college (**CUEBS News,** February 1971) to an upper division course in cell biology designed for majors (**CUEBS News,** October 1970). Perhaps the most successful investigative laboratory program which has come to our attention is a marine biology course offered each year since 1963 at Hopkins Marine Station. The manner in which guided field work, lectures, discussions, team exercises, and individual study have been woven together is particularly interesting. The influence of the course on students and community activity is remarkable. A description of the course as it was offered in 1963 has been published previously by Donald P. Abbott and colleagues and is reprinted below with the permission of the authors and publishers.

[1] CUEBS Publication 28. Investigative laboratory programs in biology. BioScience, **19** (12): 1104-1107.

Recent Changes and Some Results

According to Professor Abbott, the general philosophy and organization of the course has undergone no fundamental change since 1963. The particular species chosen for intensive study has varied.[2] During the last 2 years it was decided to take advantage of students' concern about environmental degradation by tackling problems of immediate environmental significance. In 1969, the general problem of DDT in the marine ecosystem was considered, with emphasis on Monterey Bay. According to Abbott:

> Part way through the work the results we were getting were so disturbing that we got involved at the political level. With the collaboration of legislators from our own and other districts in California, and the help of a good many other interested people, we were instrumental in getting the legislature to take action, and the California Department of Agriculture to greatly curtail use of DDT and other persistent chlorinated hydrocarbons in the state. Response of the students was magnificent. It is clear that many students want to do something constructive about the problems facing man in the modern world. Denied a chance to do this, a few may become destructive. But given a chance to do something positive, nearly all respond superbly.

In 1970, the matter of sewage pollution in Monterey Bay and Carmel Bay was tackled, not as a practical engineering

[2] Abbott, Donald P., David Epel, John H. Phillips, and Isabella A. Abbott, 1968. Undergraduate research and the biology of *Acmaea*. *The Veliger*, **6** (Suppl.): 1-4.

problem but as an ecological study. The results of the work were transmitted to local, state, and regional agencies. Local newspapers sent reporters to cover the final oral reports presented by students. According to Dr. Welton Lee, who directed the program that year:

> Although ours was not the only work on bay pollution, I think it fair to say that the input provided by the undergraduate research team was critical in important community decisions. Partly as a result of these efforts, all those peninsula communities which had not already done so, held and passed bond elections for secondary sewage treatment. The peninsula is now developing a regional plan aimed ultimately at reclamation and re-use of waste water. The students were delighted with the results. They have learned that the right kinds of decisions can be made if decision-makers are adequately informed, and that student groups can have a real impact if they will collect important needed information and present it to the right people in an objective and serious way.

There can be little doubt about the excellence of this program. It encourages us all to seek ways of offering similar opportunities for students at other institutions. In addition to providing a marvelous experience for students, it provides professional enrichment and opportunities for the teachers involved. Many may feel, however, that their institution simply cannot afford to release three faculty members to teach a single course of 25 students. It should be pointed out, however, that this course generates just as many student credit hours (375) as do many other, more "acceptable" distributions of faculty work load.

For example, if each of the three professors had taught a separate three-credit course for 25 undergraduates and a one-credit seminar for 15 graduate students, the total number of student credit hours generated would have been only 370. It may not be possible for all institutions to provide this type of enriched experience for all students, but most institutions, if they can find the will, should be able to provide similar programs for those students who are interested in becoming involved in real investigation.

At first the course was operated on a shoestring, without any outside financing. Success of the venture has attracted support from the NSF Undergraduate Research Participation Program during the last few years. This has helped immensely (1) by providing stipends for stu[illegible]o could not otherwise afford to give up part-time jobs to attend, and (2) by providing some funds for supplies and equipment which have broadened the investigative capabilities of the group.

The following is reprinted, by permission, from *The Veliger*, 6 (Suppl.): 1-6, 1964.

An Experiment in Undergraduate Teaching and Research in the Biological Sciences

Donald P. Abbott, Lawrence R. Blinks, and John H. Phillips
Hopkins Marine Station of Stanford University
Pacific Grove, California

The papers which form the bulk of this supplement to *The Veliger* are the outcome of an experiment in undergraduate teaching, conducted at the Hopkins Marine Station during the spring of 1963. The class, a group of 25 Stanford University biology majors, spent the entire 10-week quarter at the Marine Station, enrolled in a new 15-unit course called "Problems in Marine Biology," which met all day, 5 days a week.

The course was planned and conducted by a three-man faculty which included an invertebrate zoologist (Abbott), a general and plant physiologist (Blinks), and an immunologist-biochemist (Phillips), aided by a teaching assistant with experience in invertebrate development (M. Hadfield). Our general objective was to give a limited group of undergraduates an opportunity to make concentrated studies and to engage in research on individual problems in the area of marine biology.

Early in the planning stages it became clear that the faculty members were in essential agreement on certain features of the approach to be used:

(1) We would plan to start with a broad but brief survey of the marine intertidal zone. Thereafter we would concentrate our attention on a single species, which would be studied in detail in both cooperative and individual research projects. By investigating many different aspects of a single species, we hoped to get broad views and insights as well as understanding in depth.

(2) We would make our initial approach as naturalists, looking first at nature in the field. As questions and problems arose, we would try to combine the approach of the field observer with that of the experimentalist and laboratory biologist, making an effort to avoid any dichotomy between observation and experiment, or laboratory and field.

(3) We would try to be holistic in our approach, ignoring the fact that biology has been sliced up, for practical convenience, into a number of fields and levels of organization, and considering only that the biologist sees in nature a nearly endless supply of questions and problems, and that he has at his disposal a wide variety of concepts, methods, and tools which he may use in trying to answer or solve them.

(4) Finally, we hoped to plan and conduct the work in such a way that over the 10-week period the students would experience, on a miniature scale, not only the activities but also the inner feelings of a scientist engaged in research: the stimulus that comes from realizing how little man really knows and understands, the struggle to formulate a clear problem and a line of attack, the excitement and joy of inquiry and discovery, the intense intellectual and emotional commitment of the scientist to his research, the difficulties and

frustrations that may accompany the work, the pleasure of sharing results with colleagues working along similar lines, the struggle to express the results clearly and concisely on paper, and the profound satisfactions that come from even a modest creative achievement in science.

Our attempts to apply this approach and achieve these ends are chronicled below.

Out of 30 applicants for the course we chose 25, 15 men and 10 women. All had had the minimum prerequisite courses (a year of chemistry, and either introductory botany and zoology or a year of biology), and in addition the majority had studied organic chemistry, comparative anatomy, vertebrate embryology, and one or more advanced courses in the biological sciences. As finally selected, the class consisted of 2 sophomores, 14 juniors, 7 seniors, and 2 beginning graduate students. Their previous grade point averages ran from B plus to C.

Before the first day of work, the faculty tabulated the students' past records, then split the class up into six teams, each with four or five students. An attempt was made to divide up the sexes, the talents, and the course-work backgrounds represented in the class into six evenly matched working groups. Following this, the faculty went out to the Marine Station's shoreline and selected six different field stations or study areas, one for each of the student teams.

We started work during a week of good tides, with low water occurring in the late morning and early afternoon. On the first class day, after registration and orientation, the class was given an introductory lecture on marine plants. Each team was then provided with graph paper and some elementary surveying equipment (stout cord, a line level, a yardstick, and marking materials) and sent to one of the selected field stations with this assignment: survey a profile strip perpendicular to the shoreline in your study area, extending from the highest splash zone out as far as you can get with safety; along this profile, plot the distribution of the common species of intertidal plants present. The teams were told not to attempt to key out species in the field, but instead to collect all of the different kinds of plants present (insofar as these could be recognized by students in the field), to label each type with a number or letter, and to record their occurrence on the profile charts. The teams went to work without further specific instructions, but faculty members observed the field work, made suggestions where these seemed needed, and called attention to things which might be overlooked. In the afternoon, after the rising tide enforced retreat, the teams returned to the laboratory, identified their collections with faculty help, tabulated and compared results, and in class discussion tried to relate differences in the occurrence and abundance of species with differences in habitat.

The second day, after a lecture on common macroscopic intertidal invertebrates, each team worked its profile a second time, this time recording the occurrence and distribution of common benthic animals. The third day the profile exercise was repeated, the concern this time being the commoner microorganisms, both those in the water and those forming films on the surfaces of rock and weed.

This 3-day survey, though brief and superficial, allowed each student to become intimately familiar with the topography of one small area and allowed him to sample the more abundant species in each of the kingdoms of organisms present. During the survey everyone became familiar with the most conspicuous of the larger intertidal gastropods, the black turban snail *Tegula funebralis* (A. Adams, 1854), though the students were still unaware that we had selected this creature to be the hero of the course.

On the fourth day the students were given a lecture on the concepts of organism and environment and were sent out on the ebbing tide with a different type of assignment. Each team was told to "describe the population of *Tegula funebralis* in your profile area." No instructions as to what this involved or how one might go about doing it were given. We stated only that there was no single "correct" approach or method of procedure; that each team should discuss the assignment, decide for itself what was essential to a "description of a population," formulate its own methods, and get busy for the rest of the day. The students were also told that after lunch on the following day, each team would be assigned a panel of the blackboard on which to plot what they considered to be the essence of their findings, and that each team should elect one member to report to the class on (1) *what* their team had done, (2) *why* they had done what they did, and (3) what they thought they had found out. The teams went to work. The instructors observed, but tried to avoid making suggestions on what to do and how to do it.

Morning on the fifth day passed with a lecture on the sea as an environment, and in student preparation for afternoon reports. These reports, each delivered for the whole class, were most interesting. No two teams had handled the assignment in quite the same way. For example, one team laid out a line of quadrats, counted and measured all *Tegula* present, then plotted numbers and mean sizes against intertidal elevation and distance from shore. Another team with a different orientation recorded *Tegula* distribution in a semi-quantitative manner along a broad strip, noted that the species population was grouped in discontinuous clusters, set up hypotheses which might account for this curious pattern of distribution, and spent the remaining time in designing and carrying out observations and simple experiments to test these hypotheses.

The student reports brought out numerous provocative observations and raised many questions which the faculty either could not answer, could answer only in general terms, or could answer only in terms of predictions based on knowledge of other snail species. It became clear that to most of us, *Tegula funebralis* was little more than a black shell; that we knew almost nothing in detail of its food, habits, responses, tolerance limits, enemies, growth rate, life span, reproduction, and a host of other matters. We began to tabulate categories of things we did not know about *Tegula*, and out of this came the program for the work of the next 6 class days.

During this period the tides were poor for field work, and the days were devoted primarily to intensive indoor studies of *Tegula*. Lectures were used to lay a foundation of concept and background information for the practical methods and exercises carried out in the laboratory on the same day. Faculty members alternated in charge of the work, but each attended his colleagues' lectures and observed their laboratory exercises, and each made a real effort to relate his topic of the day to material covered earlier. A brief outline of the program of this part of the course follows (Table 1).

It seems worthwhile here to underline a particularly significant difference in emphasis, separating the present course from the more conventional college biology courses oriented around "principles" of a selected "field," or around particular biological taxa. The organization and stress in these courses generally reflect the viewpoint of the scientist in his capacity as a *teacher;* his stress tends to be on imparting organized knowledge. In principles courses, a firm grasp of the principles is regarded as the important thing; specific examples are regarded as illustrative rather than of great importance for themselves. In courses dealing with a specific taxon, imparting a knowledge of the group is the main desideratum. In both types the scientist, as a teacher, is trying to pass on that material within the scope of the course which is of *general* rather than merely specific significance; he is dealing in statements describing that part of the behavior of the cosmos or of its parts which seems orderly and consistent. In the principles course, organization is around the principles, concepts, or laws. In the taxon-oriented course, while generalizations are sought, principles may or may not receive emphasis; nevertheless they are always assumed to form a constant part of the background. In courses of both types, the orientation and emphasis is usually that of the scientist-*teacher*, striving to impart organized knowledge and clearer understanding.

Our own treatment of principles and other subject matter in the present course differs from the above. And the difference in treatment reflects the difference in attitude between the scientist in his role as a teacher and the scientist in his role as a *researcher*. The dedicated researcher is not so concerned with the broad and balanced view, and with orderly generalization in matters peripheral to his research; for him the most important thing is the problem under investigation. In the researcher's mind and in his hands, principles, concepts, instruments, techniques, and all the rest of accumulated human knowledge and know-how become mere tools to be brought to bear on the task of answering his question. All human experience and capability become means, to be applied in achieving his specific ends. The tools, in such a view, have no real value in themselves; those which are immediately useful are used, the others are laid aside.

And so it was in the present course. Our aim was *not* to pass on to the students a better grasp of biological principles as such, or a greater knowledge of marine snails as a group, or an increased facility in the use of scientific apparatus, or even a better understanding of *Tegula funebralis*. Our aim was to involve all of the students, intellectually and emotionally, in an intensive and comprehensive *investigation* of a common local species. We chose *T. funebralis* to work with, but it could well have been another species of animal or plant. We looked at the animal and we asked questions. Then we selected those principles, concepts, methods, and

TABLE 1

Lecture	Laboratory
Basic molluscan morphology, torsion and its consequences, the early evolution of the gastropods, and the anatomy of the Trochacea.	Dissection of *Tegula*, to work out the gross anatomy.
Physical and chemical factors in the marine environment, tolerance limits of organisms, and the concept of limiting factors.	Observations of responses of *Tegula* to various physical stimuli; determination of tolerance limits for several physical factors.
Energy sources and nutritional types of organisms; biogeochemical cycles; enzyme action in proteases and carbohydrases; methods of determining enzyme action; digestion in *Tegula*.	Determination of food of *Tegula* from gut contents; assays to determine the categories of enzymes present in different segments of the gut in *Tegula*.
Obtaining energy; transport of O_2 and CO_2; the excretion of nitrogenous wastes.	Determination of myoglobin and lactic acid in muscles; determination of hemocyanin; determination of nitrogenous waste products in excretory organs.
Receptors, nervous system, and effectors of *Tegula;* responses of *Tegula* and other snails to predators; responses of commensal species to the *Tegula* host.	Observing and measuring responses of *Tegula* to starfishes and predatory gastropods; measuring responses of *Crepidula adunca* and *Acmaea asmi* to *Tegula funebralis*.
Photosynthesis in marine algae; concepts of standing crop and productivity; intertidal and oceanic productivity; methods of measuring productivity.	Survey of food plant supply for *Tegula* in the field; field determinations of photosynthetic rate using Winkler methods.

instruments which were needed now in pursuing the answers to those questions; we introduced them, not as things of intrinsic interest or value, but as *tools for effective inquiry*. At this stage of the work, familiarity with the tool was all we expected; mastery could come later where, in particular cases, a given tool proved crucially important. But our attitude was this: the proper understanding and expert use of tools is not the prime objective of the researcher but only a necessary incidental to his work.

Discoveries new to both students and faculty were made each day. Moreover, the class was beginning to use its time and its tools more effectively in investigation. By the time the tides had again become favorable for field work, it is safe to say that the least informed student in the class knew more about *Tegula funebralis* than had the best informed malacologist in the world only a few days before. Starting with a poorly studied species, this result could hardly have been otherwise; nevertheless, the knowledge that they were breaking new ground provided a continuing source of stimulation to the class.

With the return of good tides, the students were given their next big field assignment. We posed these general questions: How does a typical *Tegula funebralis* spend its time? What is the general activity pattern of the *T. funebralis* population (1) during a 24-hour cycle of day and night, and (2) over a nearly 25-hour cycle of tides?

To facilitate round-the-clock observations, the six original teams were combined to form three teams, each with eight or nine members, and only three of the original profile areas were selected for the proposed study. Each team was instructed to set up its own work shifts, and to plan its approach, methods, and program without faculty aid. Three days were allowed for the exercise.

The first day saw a flurry of activity which ranged from the testing of fluorescent paints and other materials calculated to facilitate night observation, to the laying up of food supplies for the night shifts. Excitement in the exercise ran high and continued high, despite rains, rough water, long hours, and the frustrating difficulties of trying to follow and record the activities of a partially submerged population of purplish black animals at night. This was at least partly because information new to both students and faculty was continually coming in. Up to this time practically all of our field work had been carried out during daytime periods of low tide, when the *Tegula* population is usually highly clustered and quite inactive. In the present exercise, it quickly became apparent that the population was far more mobile and dynamic than suspected; animals dispersed, became clustered again, moved up and down, and otherwise shifted about in pronounced fashion along with changes in light, tidal level, and local current.

Much overtime went into completing this exercise, and when it was over, we found the team oral reports absorbing, as much for the student attitude reflected as for the findings on *Tegula*. As one faculty member remarked to a colleague after the reports, "Excellent! Who would have thought you could get a group of 25 Stanford undergraduates so stirred up over the doings of a little black snail?" Reports were followed by a reassessment of the things we had found out about *Tegula*, and further, a listing of some of the questions, problems, and good leads that remained. The list was a long one.

Students were given the weekend and the first part of the following week to survey the list, do a bit of reading and perhaps a bit of pilot investigating, and to select for themselves individual problems which would occupy them for most of the remainder of the quarter. They were lectured on biological literature sources and the use of a research library, and instructed how to use the abstracting and indexing serials, such as Biological Abstracts, Chemical Abstracts, and the Zoological Record. Toward the end of the fourth week, each member of the class handed in a written prospectus for a research problem. This was gone over very carefully with a faculty member, revised, resubmitted, and often rewritten again. A real effort was made to get students to frame their problems in fairly concrete terms, to formulate them in terms of specific and answerable questions, and to limit them to such a degree that there was a reasonable hope that some answers could be obtained before the end of the quarter.

The fifth week of the class began with a talk from each student, covering what his problem was, and how he was planning to tackle it, or at least start on it. Some idea of the scope of the projects attempted may be gained from the following list of abbreviated project titles.

- Distribution and movements of the *Tegula funebralis* population.
- Factors governing the upper and lower limits of distribution of the *Tegula funebralis* population.
- The activity pattern in *Tegula funebralis*.
- Orientation and dispersion of *Tegula funebralis* with respect to current.
- Responses of *Tegula funebralis* to starfish and gastropod predators.
- Interactions between populations of *Tegula funebralis* and hermit crabs.
- Photoreception and responses to light in *Tegula funebralis*.
- Chemoreception in *Tegula funebralis*.
- The anatomy of *Tegula funebralis*.
- Structure, growth, breakdown, and repair of the shell in *Tegula funebralis*.
- Algae on the shell of *Tegula funebralis*, in relation to the distribution, food, and feeding of the commensal limpet *Acmaea asmi*.
- Attraction of the larvae of *Acmaea asmi* to *Tegula funebralis*.
- Dispersal of the young of the commensal gastropod *Crepidula adunca* to new *Tegula funebralis* hosts.
- Reproduction and larval development in *Tegula funebralis*.
- Food preferences and feeding in *Tegula funebralis*.
- The carbohydrases in the gut of *Tegula funebralis*.

The proteinases and lipases in the gut of *Tegula funebralis.*

Yeasts living in the gut of *Tegula funebralis.*

Diurnal fluctuations in the O_2 consumption of *Tegula funebralis.*

Production and fate of lactic acid in the muscles of *Tegula funebralis.*

Hemocyanin of *Tegula funebralis.*

Excretory products of *Tegula funebralis.*

In a few cases the projects above were handled by two students working in close collaboration, but the majority were carried out by individuals. Each student was assigned a faculty advisor who aided in finding references and equipment and in getting the project started. For a time there were real problems of space and equipment. Also, it very quickly became clear that no real class work schedule was possible, and that the laboratory would have to be open and available 24 hours a day, 7 days a week. No formal lectures or labs were therefore held. Students were expected to report to their advisors periodically, but student independence and initiative were encouraged as much as possible. There was surprisingly little "goofing off."

By the middle of the seventh week, work had progressed to a point where the findings of one student were beginning to throw light on projects tackled by others. We therefore scheduled a series of small conferences, each attended by a few students working on interrelated problems and by one or two faculty advisors. Topics around which discussions were organized included the following:

Distribution of *Tegula funebralis* and ecologically related species, and factors affecting that distribution.

Sensory reception.

Commensals and predators of *Tegula funebralis.*

Food habits and feeding.

Digestion.

General physiology.

Structure, development and growth.

In most cases, an individual student was assigned to two different groups, so his findings could be considered from at least two different points of view. Students were asked to bring in their data in organized form, and to be prepared to present and discuss them with others.

We hoped the interchange in these discussion groups would in some ways compare with that experienced at small scientific meetings limited to investigators working on closely related problems. The results in most cases did not live up to our expectations, and in retrospect it is clear that those expectations were too high. A number of students were still struggling with methods, and discussions in some areas centered on these. Some students brought in quantities of undigested data. Only a minority presented findings effectively in the form of tables or graphs. Among the lessons learned was this: that unless problems and findings were presented in clear, concise, organized form, and illustrated graphically in some manner, the investigator failed to get much across to his audience, and discussions lagged or never got started, or were restricted to comments by the faculty advisors. Nevertheless, it appeared at this stage of the work that the findings of a majority of students included some small but original contributions to science, of particular interest to malacologists.

With this in mind, the faculty contacted Dr. Rudolf Stohler editor of *The Veliger*, presented a brief outline of what the student group was doing, and inquired whether or not papers resulting from the course might be considered for publication in that journal. Dr. Stohler's response was immediate; the course sounded interesting, and any papers resulting from it would be considered for publication providing they passed editorial board inspection. There was no guarantee that all or any papers would be accepted, but if a sufficient number proved suitable, it might be possible to issue a sort of "Symposium on *Tegula*" as a supplement to *The Veliger*. Word of this response was passed to the students, and this provided an additional stimulus.

The eighth and ninth weeks of the course passed in research and in conferences between students and their advisors, and the lights in the laboratory burned very late. A deadline for turning in final drafts of papers to faculty advisors was set at the end of the ninth week, a full 7 days before the end of the course, in order to allow time for rewriting. In a lecture on the subject of writing and illustrating scientific papers, it was stressed that not only must a scientific paper have something to say, but it must say it in an organized fashion, concisely, and with unequivocal clarity; students were referred to current biological periodicals for specific examples.

Oral reports on research projects occupied three successive mornings of the final week of class. These talks were attended not only by all members of the class and faculty but also by other graduate students and investigators in residence at the Marine Station at the time. An effort was made to hold the talks under circumstances approximating those of a regular small scientific meeting. Individual reports were limited to one-half hour each, and were accompanied by illustrations and graphs from student papers, projected by means of an opaque projector. The reports went very well. For the most part they were organized and had been rehearsed, and were delivered in a manner comparing favorably with that of professional scientists at meetings. We were exceedingly proud of student performance here.

All of the remaining time during the last week went into criticism and revision of the written research reports. Despite instructions, most of the written reports resembled first drafts of undergraduate term papers rather than scientific manuscripts. The best were none too good, while the worst were longwinded, chatty, poorly organized, and frequently incoherent. The papers were gone over in student-advisor conferences, criticized in real detail, sentence by sentence, torn apart and reorganized, and sent back for rewriting. The rewritten version was also criticized, and often sent back for further revision.

UNDERGRADUATE INVESTIGATION IN TROPICAL ISLAND ECOLOGY

Louis V. Wilcox, Jr.
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Three years ago, Earlham College undertook the development of programs focusing on tropical biology. Two programs were established, including a spring term in marine biology at the University of South Florida, and a summer investigation program in tropical island ecology in the Bahamas. The latter program is discussed in this paper.

The general objectives of this program were not unlike those of Abbott, Blinks, and Phillips (1964) [see preceding article in which there is a reprint of their paper], but the operation of the program was decidedly different. The objectives of our program were as follows:

1. To involve undergraduate students in a variety of aspects of the ecology of mangroves, or closely related areas.

2. To focus upon problems, rather than selected disciplinary approaches. The students were encouraged to: (a) examine the problems in an area rather than attempt to function as either a field biologist or laboratory experimentalist; (b) utilize a holistic approach in searching for answers. Disciplines and subdisciplines were looked upon as sources of information to solve problems, not as the basis of an approach. The students had access to the literature from these many areas and were trained thoroughly in the use of the library (Kirk, 1969). In addition, the students had available to them several noted authorities during their investigation and were encouraged to contact other authorities upon their return to the United States, particularly in the areas of systematic identification.

3. To allow the student to experience the life of a scientist. This included many realizations, not the least of which was the status of man's understanding of his world, the emotional side of the scientist, the large amount of "routine" involved in scientific investigations, the thrill of discovery and learning, and the dedication required to learn. In addition it was hoped that the student would learn the satisfaction that comes from a creative accomplishment and that he was, in fact, capable of this creative accomplishment.

How did this approach work in reality? In brief, the first year (1968) was spent in doing some background investigation and planning the approach we would use, and the following two summers (1969, 1970) were devoted to actual operation of the program.

Five undergraduates spent the better part of June and July 1968, with me, on the island. We initiated studies on the structure and distribution of mangroves in the Jewfish Chain and completed an inventory of populations extant in the area. Potential problems that might be investigated profitably by undergraduates were enumerated. On the basis of this initial survey and in consultation with the participating students, the program was operated in the following manner in 1969 and 1970.

Students selected for participation spent spring vacation (10 days) on the cay surveying various problems that would lend themselves to investigation and participating in on-going investigations in the mangroves. The purpose of this preparatory survey was to give students an idea of the type of problems which they could investigate in the unique environment of the station. Following this trip, each student spent the 10-week spring term: (1) selecting a problem for investigation; (2) completing a literature search on his selected problem; (3) planning out his study in detail; (4) purchasing all necessary equipment and supplies; (5) participating in eight evening seminars to discuss the various proposed investigations; and (6) making an oral presentation on his proposed investigation. During this time, the students also received instruction in the use of techniques pertinent to their investigation. Thus, when a student arrived at the cay in the summer, he had already identified a problem and prepared himself to pursue its solution vigorously and professionally. At the end of the summer, each student was expected to report the results of his investigation in a form that would be suitable for publication.

The group of students that applied for the program in the spring of 1969 was not much larger than the number of spaces available. With time, the number of applicants has increased to the point where there are about twice as many applicants as positions. Ten students from Earlham College participated in the 1969 spring trip, and these same ten students carried through and participated in the summer of 1969. They did their preparatory work for the summer investigation at Earlham during the spring term. Five students from Tufts University participated during the summer also. The Tufts students had no spring preparatory period prior to the trip, though most of them had visited the cay the previous January. They needed far more help than the Earlham students since they had done little or no planning. There was a total of 15 students conducting investigations during the summer of 1969. The prime responsibility for directing the research was on the shoulders of the *students*, though I and four visiting scientists provided assistance.

During 1969, all living and research activities were conducted in a small cottage which consisted of a living room (19 ft x 18 ft), two bedrooms, three screened porches, and an extremely small kitchen. We lived and worked coeducationally in very cramped quarters. At first, we thought this would be a detriment to the operation of the program, but it turned out to be one of the stronger features. We lived and worked together 24 hours a day and learned a great deal about the feelings and emotions of one who is intensely involved in an investigation. This mode of living and working has been continued, albeit the intensity is not as great with the completion of our new 4900 sq ft laboratory building in 1970. This building was made possible by a grant from the Arnold Bernhard Foundation.

With the extensive work done during the spring, there was no need for introductory lectures, discussions, or other types of preparatory activity upon arrival on the cay in the summer, except for the students from Tufts. The morning following arrival, the students simply got out of bed, ate breakfast, and went off to work on their investigations. Living as we did precluded the necessity of planned meetings, though we did have an informal evening seminar each week to discuss problems encountered in various investigations.

Investigations conducted during that summer were as follows: habitat preference in intertidal crabs; factors influencing distribution of molluscs in mangroves; mangrove fish populations; factors influencing the distribution of algae in mangroves; the role of *Avicennia nitida* and *Laguncularia racemosa* in mangroves; primary productivity in mangroves; factors influencing the distribution of invertebrates on sand flats; the nesting behavior of the white-crowned pigeon in mangroves; pubescence in *Conocarpus erecta;* a survey of mangrove insects; and bush medicine in the Exuma area. Five of the students who conducted the investigations had just completed their freshman year, four their sophomore year, and six their junior year. Three of the papers from this work have been published (Wilcox, Patton, and Coriell, 1969; Semple, 1970; Yocom, 1970). Four other papers are in preparation for publication and the work of four other students has contributed to other papers presently in preparation for publication.

The students who participated in the summer of 1969 had a varied background. All were biology majors save for one who was majoring in geology. All had taken our introductory course (two, 10-week terms) and the more advanced students had taken two or three upperclass biology courses and three 10-week terms of chemistry. No emphasis was placed upon particular prerequisites, however. Rather, the emphasis was placed upon the willingness and interest of the individual to become involved in a demanding investigation. Three criteria were used for selection: (1) willingness to work and get one's hands dirty; (2) psychological make-up for living in a small, tight-knit group on an uninhabited island; and (3) academic record. In terms of batting averages, two students flunked; of those now graduated, five out of six are in graduate school (one each in ichthyology, zoology, botany, medical school, and marine biology); of those still remaining in undergraduate school, four are making plans for graduate school. Those already in graduate school are for the most part pursuing the same general topical area investigated during the summer of 1969.

In 1970, 16 students participated in the spring trip. Of these, ten were selected for the summer program, nine from Earlham and one from Carleton College. Two of the ten had been involved in the program the previous summer. There were three students in this group who had graduated; six who had completed their junior year; and one, the freshman year. Of the three graduating seniors, two are now enrolled in graduate school and one is fulfilling his military service obligation. The background of these students was very similar to that of the students in the summer of 1969, except that this group had taken more biology courses. The problems that were investigated were as follows: the role of sunlight and dessication on the distribution of algae in mangroves; the reproductive behavior of *Strombus costata;* distribution and behavior of *Littorina angulifera;* feeding behavior of *Cyclura figginsi;* factors controlling pubescence in *Borrichia arborescens;* factors controlling the distribution of algae on sand flats; primary productivity in mangroves; and nesting behavior in mangrove birds. As you note, students have branched away from investigations only on the intertidal area. Five of the papers produced in 1970 are presently in preparation for publication.

Each student enrolled in this program received one academic credit (3⅓ semester hours) for the work conducted during the summer months, though not all participants registered for the credit. There is no academic credit for their summer work—6⅔ semester hours. In addition, there were funds available at the beginning of this program to defray the costs of students participating in the program. These monies have decreased to the point that during the summer of 1970, only about half the students received a portion of their expenses. Starting with 1971, students will be financing the trip entirely on their own in the same manner that they pay for enrollment in other portions of the college program. It is difficult to evaluate the role that this financing played, though the students felt that it played a rather significant role. A number of them stated that they would have been unable to participate in the program had it not been for the funding. We look forward to the impact of no stipends and two academic credits during the summer of 1971.

But, how well did we do in achieving our goals?

From the student's point of view, the most significant component of the program was not spelled out in the original set of goals and objectives. They feel that the greatest advantage to this program has been what they learned by living and working in a very confined space over a period of 8 weeks. Specifically, they point to lessons they learned about themselves in terms of their interactions with other people and their effectiveness in learning; their understanding of what it means to accept responsibility within a group; and the understanding they gained about how people function (including themselves). They are quick to point out that these accomplishments are really within the prescribed goals and objectives as this is helpful in maturing as an effective scientist.

It would appear that there were several reasons for the success of this program. One was the extensive preparation prior to the summer program (the necessity of the preparation stage is discussed elsewhere [Holt et al., 1969]). Each of the students did an extensive literature search on his topic and also wrote up his research proposal. Another reason for success was the fact that students and instructor lived and worked together 24 hours a day. In the early part of the program, we had no choice. Later, it was decided upon mutual agreement that we would all live and work together. Living together, when we were all struggling toward the same goal—solution of closely related problems—led to an *esprit* that contributed very significantly to the realization of the objectives. The stated expectation of publication added considerable stimulus. All students recognized the potential benefits should they publish as an undergraduate.

From my perspective, a great deal of the success of the program can be attributed to the time spent during the spring trip and during the spring term in preparation. It was frustrating and difficult for all concerned because we did it on an overload basis. But the rewards in terms of creative accomplishment made it more than worthwhile.

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TEACHING PLANT SCIENCE BY INVESTIGATION

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Anyone who professes to teach the sciences cannot become involved with students, their views and thoughts toward science, and their attitudes toward education without being stimulated to look deeper into himself and the course he is teaching. A teacher only listens to students for a short time, if he listens at all, before he recognizes that his goal and the students' goals are often quite different. No two students have identical goals for courses they are attending or for their education. A second basic element (?) is that students' backgrounds are varied according to their basic environment and their different genetic endowments. Becoming aware of these individual differences and attempting to cope with the inherent problems of presenting new subjects make teaching the exciting challenge that it is.

This paper describes the first-year course in botany at Colorado College. The course is designed for (1) those persons who indicate a special interest in the biological sciences and are trying various courses in the College in an attempt to select a major area for specialization, and (2) those upperclassmen who are science majors and are interested in increasing their knowledge of plants. It is structured on the premise that this is the first college experience in botany for these students and that the backgrounds and degrees of interest vary. The students enrolling in the course have expressed some interest in learning something of the life processes, structure, function, and evolution of plants and have a personal interest in the investigative nature of science in solving problems.

The course is not required and the teaching staff can assume that the people entering the course have done so under their own volition. This important concept—the encouragement of students to select and choose wisely among those courses available to them—is considered to be the first important step in a liberal arts education. Although the students have an academic advisor, they are encouraged to visit with all the faculty in developing a program tailor-made for them. All of the faculty in the department of biology and a number of faculty members in other departments encourage their students to enroll in plant science, but if a student feels he is not interested in the subject and other courses are of greater value to him, he is not intimidated or browbeaten into an unbearable situation.

Students are informed on the first day of class that if at any time during the semester they wish to discontinue the course, they may drop it and not receive a failing grade. Years of teaching experience have shown that students lose interest in college classes for many reasons. Occasionally, such problems are personal matters and students would rather not discuss them, but most often it is simply a case of a student's taking too many credit hours or finding that one course requires too many hours of preparation each week. In this situation the student may be encouraged to drop plant science in order to lighten his load and to re-enroll at a later date. Invariably these students do return and enter the course, with a personal commitment and enthusiasm to complete it. Under older and more awkward grading systems, students would have been forced to take a failing grade and to return to the course to remove an F grade they may or may not have deserved.

The classroom-laboratory facility for this course is designed for 24 students. Because of the type and level of student investigations, this presently appears to be the upper limit. This means that 48 students may complete this one-semester course each academic year.

Every effort is made by the staff to be available to students. Although the course is scheduled to meet from 9:00 a.m. until 9:50 a.m. on Monday, Wednesday, and Friday and from 8:00 a.m. until 9:30 a.m. on Tuesday and Thursday, the students are informed early in the course that the instructor and the assistants are available to them from 8:00 a.m. until 10:00 a.m. Monday through Friday. They are also told that the laboratory and greenhouse will be open on Saturday and that special arrangements can be made for continuing their research projects on Sunday.

To support this program we are developing a plant-science student research library in the laboratory; furthermore, students are encouraged to make use of the instructor's personal library of books and journals. As part of the program each student pays a $5 Xerox charge so that when articles pertinent to his interests are identified he may obtain a copy for his library. In such a program, books and journals are occasionally lost, but—more important—they are used. A personal survey conducted in 1968 revealed that although The Colorado College library has satisfactory holdings in the botanical sciences, large numbers of books and journals were used only occasionally in the past 20 years and many important books purchased in the past 10 years had never been checked out to a single person—faculty or student. It is my personal view that students, teachers, plants, and the literature must be allowed to interact in a central location or "where the action is," the laboratory.

Almost daily at the beginning of the semester the students are also reminded by the instructor, "I (the teacher) work for you, and you do not work for me. You pay my salary and I hope you will use me." Surprisingly, many students are unaware of this situation in American education and some would be pleased to continue to hide behind the skirts of college requirements, parental demands, and teacher authority for protection from the reality of intrinsic learning. Here, students are continually confronted with the question, "What do you wish to know about plants and how can we help you learn?"

Another objective in this program is to remove student-to-student competition. We feel so strongly about this that we have incorporated this person-to-person relationship into the student grading system. As long as students are working to get ahead of other students, they cannot be fully committed to assisting their colleagues in learning. A classroom without open and honest peer-group interaction may resemble a hog trough rather than a center for inquiry. We encourage students to assist one another and to call on associates as well as instructors when they are having difficulties. Not only is this attitude considered sound pedagogy for the classroom, but it strengthens the students' understanding of the nature of scientific inquiry. Science functions at its highest level when there is diversity of thought in an open environment and where risk-taking is encouraged. The removal of peer-group competition demands that each student examine his personal objectives and abilities and establish an attainable goal for himself. This is one of the most difficult objectives for the students to comprehend; for after working to surpass their friends for 14 or 15 years in American education, the sudden change in behavior is difficult to master.

The first 6-8 weeks of the course (depending on the rate at which the students complete the work) are devoted to achieving content objectives and the remainder of the semester is devoted to individual research and a seminar.

Content Objectives

Experience has shown that most students coming into their first formal experience in the plant sciences are lacking in content knowledge of plants. When they are faced with the question, "What would you like to learn regarding plants?", their reply is either "I don't know" or "Just a little bit but not too much." The rare exception is the sophomore or junior student who blatantly states, "I desire a Ph.D. in botany."

Due to this wide variation in student interest, the content portion of the course is composed of 16 descriptive content packages of information which are based on the results of scientific inquiries in the plant sciences. These packages are composed of statements, diagrams, and questions plus numerous references designed to direct students' efforts in their study. The topics selected are taken from what is currently known about plants and the terminology used by botanists. The students are reminded that only a small portion of the total available information is available in these packages. They are also continually told that they are only reviewing a bit of botanical research history and that during this phase of the course they will not be involved in the scientific process of designing and solving problems in the plant sciences.

The laboratory materials are usually available to demonstrate three to five of the content packages at any one time. Students may move at their own pace within this range of materials. A most difficult task is to maintain the necessary living material for a single package for more than a one-week interval.

Students new to the program tend to procrastinate; in this self-directing situation where the instructors are available but never checking attendance or requiring participation, at least one-third of the class will start to fall behind. One important conflict is that most of the class is enrolled in organic chemistry and calculus, which have regular examinations and required assignments. These students continually come to me with this problem and at times almost encourage me to become an equal threat on their time by requiring them to take the content tests at set intervals. These students invariably state their interest in studying plants—if only time would permit. This opportunity is used to encourage them to take a hard look at their education and what they hope to achieve in college. Past experience has shown that over 60% of the students regularly complete all 15 content packages; less than one-third of those attending will usually omit from one to five of the packages.

The testing program in this content portion of the course is designed to allow the students to request the examination over each content package as they feel they are properly prepared. If they receive a score on the examination that satisfies their objectives in the course, they are free to progress to the next package. If they are not satisfied with their score on the first examination, they are encouraged to restudy the package and then take another examination over the same material. There are two or three examinations over each package; students may take none of them or all of them depending on their objectives. A student interested in raising marijuana would have little need for spending much time on the evolution of algae and fungi, but a student who intends to study forestry or obtain a Ph.D. in botany should plan to attain a high level of understanding of the theoretical side of the subject. Students study accordingly. This is another part of the plan to encourage the students to examine their own objectives.

All examination scores are posted on the bulletin board by student number, so that each student may see where the class is at all times and how he is progressing in comparison with the other students. I have never maintained a grade book for this course, for I find it unnecessary. I am not interested in the scores the students receive unless they are interested in discussing their scores with me. If students are reaching their objectives I am pleased; if they are not achieving their objectives I want to assist them.

Formal lectures are never presented unless requested by the students. Usually the lectures are requested only when the students are having difficulty. In understanding some aspect of photosynthesis, respiration, or water movements in plants, or in comparing life histories of several of the algae or fungi, such lectures readily slip into discussions, because the students are prepared to ask specific questions that are relevant to their problems at that particular time. The need for these lecture discussions is usually identified by the instructors in the laboratory during small group discussions and are scheduled a day in advance. Those who are interested may attend and those not interested, or not in need of help, may plan to stay away.

The second portion of the semester is divided into two parts: one directed at individual student research projects; the other directed toward a class seminar dealing with the scientific literature in the plant sciences.

Individual Research

During the last 8-10 weeks of the course (depending on the rate at which individual students complete the content packages), each student designs one or more investigations based on a botanical problem he has identified and pursues a solution to the problem or problems as time permits. These student investigations are selected, designed, and conducted with regard to freedom to interact with all available literature, observed problems in the immediate environment, peer-group interaction, and all the assistance the instructors can possibly provide. The students are encouraged to design and attempt several problems until a specific solvable problem starts to unfold. Time, materials, and equipment are limiting factors as in all scientific research, but these factors are taken into consideration as the student designs the investigation.

We have discovered this is the first time most students have ever been allowed to seek an answer to one of their questions in a science class without the threat of failure if they do not attain the "desired" result. It is also at this point that the staff must realize its greatest commitment to assisting the students. This kind of assistance often entails making long-distance telephone calls to order necessary chemicals, making arrangements for students to travel to other campuses to visit with a professor doing research in a similar field, getting the student into the field to gather specific information about a plant community, or assisting a student to obtain necessary reprints of articles not in our library. Faculty members in other departments often come to the rescue of students by providing assistance in biochemistry and in computer programming. Through such interaction students come to appreciate the interrelationship that exists among people who wish to solve real problems. They feel the anxiety created by faulty equipment and sloppy techniques. Frontiers of science that were many textbooks and courses away start to come closer, and in a number of cases the fun of dealing with a real problem has been continued into further study and research the following semester.

The teachers must not be tied to "doing their thing"; but rather, they must be continually assisting students in locating and interpreting published information that will assist the students in adding information to their knowledge bank. An exciting by-product of this class is that the teachers must continually be reading publications that they would never consider reading if they were teaching the traditional botany course or if they were conducting research in one specialized field.

In this class the teacher soon recognizes that honesty is the only possible rule for survival. Faculty titles and rank which form the punitive facade of most college and university lecture halls give way to the fun of working together on a mutual problem. The juniors and seniors enrolled in the course who have a working knowledge of specialized techniques brought from other courses come to the assistance of other students to save the instructor many embarrassing moments. They teach the teacher a great deal.

Recent student investigations have dealt with the following topics: An Electrophysiological Study of Phytochrome: Red Far-Red Response in *Lactuca Sativa* L.; Effects of Specific Amino Acids on Streaming Behavior in *Physarum polycephalum* L.; Chromatographic Separation and Comparison of Photosynthetic Pigments in *Ulothrix* and *Vaucheria;* Photoperiod Control of Flowering in *Brassica campestris* L.; Bioelectric Potentials in Plants; Rock Lichens of the Pikes Peak Region; and The Effects of Blue Light of Various Duration on Two-Dimensional Growth in Fern Gametophytes.

During the final week of the course, students prepare typed scientific manuscripts covering their investigations. The manuscripts are xeroxed and distributed to all members of the class. Also during this week, each student is permitted 15 minutes for presenting his research project to the class.

Under this plan, each student not only receives a copy of all student papers, but at the same time has an opportunity to question other members of the class. This aspect of the course gives the students an opportunity to be exposed to a number of topics that could never be reached in a traditional course, to review a number of varied research designs, and to become an important part of the course-evaluation scheme.

Seminar: "Inquiry into Inquiry"

This seminar has been established as a frontal attack on the problem of introducing students, early in their careers, to the scientific literature in biology. The seminar is directed at the nature of the inquiry process. It is a study of procedures followed by botanists in solving problems in the botanical sciences.

This aspect of the program was an outcome of the author's participation in the Mid-Continent Regional Educational Laboratory (McREL) and the Biological Sciences Curriculum Study (BSCS) conferences that developed the document entitled *Inquiry Objectives in the Teaching of Biology*. One chapter of the document by Prof. Joseph J. Schwab was entitled "Inquiry into Inquiry"; we have borrowed the title because it does describe the intent of our seminar. The introductory statement describing "Inquiry into Inquiry" is as follows:

> There are means other than direct laboratory experiences to involve students in inquiry. One means consists of allowing students to critique scientific papers, abstracts, or other reports to discover the variety of logical patterns in scientific investigations carried out by scientists and science students. This type of activity can be challenging and can help students develop skills and appreciations of critical reading and thinking that are generalizable to other types of communication.

Copies of published botanical papers are reviewed by the students for the content in terms of botanical data—and more important to this seminar—for the procedures followed in stating and solving the problem. Students are encouraged to compare the research design of botanical papers with those of other scientific disciplines.

After the students have had an opportunity to discuss and compare several scientific papers selected by the instructor, they are encouraged to start a thorough search of the literature for articles related to the research problem they have selected for study. At this point, a number of the students seem to pass through a revival of the spirit of science. Content packages, individual research problems, and the effective environment necessary for conducting scientific investigations fuse into a single relationship. Many of the students see themselves for the first time actually involved in what scientists do. They become aware that they can contribute through what J. Bronowski has called "the habit of truth."

At the same time, we must recognize a group of students who are now ready to admit that they would like to stay in the stands as observers rather than move on to the field and participate in the game of science. It would appear that many of those who taste but never eat cannot freely give themselves to the activity. It is sad to observe their struggle and yet not be able to assist them in discovering where and how they fit in; but the satisfaction comes in knowing you have helped them to decide against one kind of activity.

Grades and Evaluation

Grades. To bring a traditional system of "teacher grading students" to bear on this program would mean the destruction of most of the affective behaviors that have been encouraged throughout the course. The students attending the course are encouraged to see grading for what it actually is: a system of segregation that serves only to establish barriers between people rather than bringing them together to assist one another in solving problems.

Early in the course the students are informed that the instructor is not qualified to sort and classify human beings. This attitude comes as a shock to students who have spent 13 or 14 years in the American educational system making the "right" grades and preparing to get into the "right" college and are now counting on attending the "right" graduate or medical school.

Recently, The Colorado College has made a basic change in the grading system that allows greater freedom for the teacher in determining final course grades. We have moved from the A-B-C-D-F to an Honors-Credit-No credit system for most courses. This has allowed the author to experiment with a student-owned and operated grading system.

Rather than retain a grade book in which we record either objective scores for elementary kinds of rote memorization or purely subjective numbers or letters based on my feeling toward the students and the materials they might present to an authority symbol, we have established a system that allows the class to select from their number those students they feel are qualified for honors. They are asked to rate their peers in three categories which are based on content scores received on content packages, individual research projects and ability to prepare and present a scientific paper, and a number of affective or attitudinal behaviors that appear to be most important in dealing with other students in an environment conducive to scientific research.

The students soon recognize the easiest and safest system of sorting and classifying students is based on content scores, but they are quick to admit there is a great deal more to the plant sciences than is revealed in the content scores that have been posted on the bulletin board. Since a content pre-test and a content post-test are taken by all students and there are individual package tests for the 15 content packages, the students come to appreciate those of their peers who came to the course with a poor background. Even though they did not receive the highest score on the post-test, such students may have shown an impressive increase in their content knowledge.

All the students have had an opportunity to read the papers prepared by their associates, to hear the students present their papers in a "scientific meeting," and to read and evaluate a number of published scientific papers in the field. They can now start to function as editors of a scientific journal or as referees in a scientific discipline. One of the most impressive aspects of this program has been the serious nature of the evaluation process for those who know they will not be considered by their peers for honors but feel personally committed to a realistic system of evaluation.

All students are supplied with a list of the affective behaviors that were included in the BSCS-McREL document and considered important to success in the inquiry process. These include such qualities as curiosity, honesty, openness, reality orientation, risk-taking, objectivity, precision, perseverance, and respect for theoretical structure. Aware that with our present punitive knowledge for evaluation of these characteristics any rating of the class is highly subjective, but knowing that teachers and professors have for years considered themselves fully qualified from their pontifical position to make such judgments, it was my guess a group of students could never do a poorer job of rating and grading than that done by college professors. The most important conclusion derived from this portion of the peer-group grading system is that students know students better than this teacher knows students.

All student comments and ratings are public domain and are available for all to view. Students are told to be candid in all remarks following their ratings; and indeed, when they realize that the teacher does not stand in judgment, they will say exactly why they rated their colleagues as they did. The following are a few student comments concerning particular individuals:

"The guy is smart but he just isn't open; I don't trust him." "Bill has it all the way—content, cognitive, affective, and looks. I sure wish he'd ask me for a date." "I think John deserved honors, but he never came to class or participated in lab." "If this guy ever gets to be an M.D., the world will suffer—he uses everyone around him." "I don't think you know it, Carter, but Brent worked like a dog in this course."

Once the student ratings are turned in, it is possible to quickly order the group and to identify those students the class has selected for honors. I have never interfered with the class decisions for I have never felt a need to do so; but if I ever sensed an injustice, I would call a class meeting and present my case. If I ever felt neglect on my part had discriminated against a student, I would feel obligated to identify my failure and to ask the class to reconsider this person.

Evaluation

Although I am strongly opposed to present grading systems, I strongly support evaluation. Here I am referring to a personal evaluation or criticism that does not become a permanent record to be used at a later date for or against the person. Most students are interested in the personal views of the teacher concerning their abilities and the level of their work. In the situation previously described, all but a very few of those students who come to this course are interested in improving their skills and abilities. For this reason, and since I do not make the final judgment of each person's grade, I am free to provide all the assistance possible to their success. I read and offer suggestions to improve their research papers; for example, I may suggest different approaches in presenting graphs and tables to clarify a particular point. In this system one need not ever withhold information or ideas, but one can give his views and opinions to the best of his ability in any situation that develops.

Although the program has many weaknesses and shortcomings, we are attempting to remove the threats from education and to humanize the teaching of the plant sciences. It is my view that inquiring into plants cannot be fun for all people, but it can be interesting and exciting for many.

THE BIOLOGY-CHEMISTRY INTERFACE SERIES

Light and Living Matter, Volume 1: The Physical Part
by Roderick K. Clayton, McGraw-Hill Book Company, New York, 1970, 148 p.

and

Introduction to Organic Reaction Mechanisms
by Otto Benfey, McGraw-Hill Book Company, New York, 1970, 270 p.

In 1965, the Commission on Undergraduate Education in the Biological Sciences (CUEBS), the Advisory Council on College Chemistry (AC_3), and the Commission on College Physics (CCP) brought together a group of biologists, chemists, and physicists to study ways to improve teaching in areas of mutual concern to two or more of the disciplines. After considering the interface between chemistry and biology, they suggested that a series of monographs, prepared for elementary college-level students in either biology or chemistry, might serve a useful purpose. Specifically, they thought that the monographs should be designed to provide enrichment material on topics that are currently treated only briefly in formal courses. Five years later, the first two volumes in the suggested series have appeared. They are *Light and Living Matter, Volume 1: The Physical Part* by Roderick Clayton and *Introduction to Organic Reaction Mechanisms* by Otto Benfey.

The two authors approached their tasks in quite different ways. In *Light and Living Matter*, Clayton chose to begin by outlining the theoretical models which scientists have constructed to account for the physical properties of light and matter. As a result, the first 25 pages treat topics such as light as an electromagnetic wave, light as a stream of particles, and quantum theory. The style and content are not unlike those found in several current introductory physics texts. Having considered the properties of light and matter separately, Clayton turns to a consideration of the interaction of the two. Topics treated include the absorption and emission of light by matter, metastable states and photochemistry, de-excitation processes and transfer of excitation energy. Again, he chooses to rely heavily upon diagrammatic and mathematical models of relatively simple systems with almost no reference to biological materials. For example, in the section on the transfer of excitation energy he begins with the following sentence: "Consider a dye having two intense absorption bands, one in the blue part of the spectrum and one in the red." A theoretical consideration of this artificial system continues for three and one-half pages. Only at the end of this section does he mention, in two sentences, that the principles involved are of great importance in photosynthesis.

The second major section of the monograph discusses the measurement of light and its absorption by matter. Since consideration is given to both the theoretical and practical problems associated with measuring light absorption and emission, this section will be of particular interest to students or novice researchers who wish to make use of light as an analytical tool. Supplementary material in the monograph includes a list of problems (with answers provided) and appendices on the Plank Radiation Law, the relationship between absorption and fluorescence, components of optical systems, and how to connect a photomultiplier. A second volume of the monograph is planned by the author. It will focus more directly on living matter.

The approach taken by Benfey in *Introduction to Organic Reaction Mechanisms* is quite different than that taken by Clayton in *Light and Living Matter*. Rather than starting with theory and models, he begins with an analysis of a particular reaction—the nitration of benzene. The author uses this reaction to refresh the reader's memory of basic chemical concepts and to generate an answer to the question "What is a reaction mechanism?" Building on this introduction, Chapters 2, 3, and 4 provide a detailed study of the three key factors that influence the rate and direction of chemical change: concentration of reactants, the geometry of the molecules, and energy relations. In each of these chapters, the principles are developed from a consideration of specific chemical systems, some of which are of considerable importance to living organisms. Chapters 5 and 6, in which the author considers the reactions of the carbon-carbon double bonds and most of the important organic reactive groups, should prove to be particularly useful to students of molecular biology. Rather than placing study questions at the end, the author effectively weaves them into the text in programmed instruction style. This feature contributes significantly to the effectiveness of the book as a self-instructional device.

Both monographs achieve the objective for which they were designed, that is, to provide enrichment material on topics that are currently treated only briefly in formal courses. Most undergraduate students and many biology teachers will find both monographs very tough to tackle alone. Because of the novel and creative way that Benfey has approached his subject, I feel that *Introduction to Organic Reaction Mechanisms* will contribute significantly to the improvement of undergraduate instruction. Volume I of *Light and Living Matter*, on the other hand, does not add significantly to the instructional material which can be used to teach undergraduate students about light and matter. Hopefully, Volume II of this monograph will prove more useful to biology instructors and students.

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A MINICOURSE: MODULES AND MODULE-MAKERS

Joan G. Creager
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That interaction between people is the key ingredient in any conference was again demonstrated at the CUEBS Minicourse on Modules, held at the Easern Campus of Northern Virginia Community College on March 19-20. The stated purpose of the minicourse was to provide the 60 participants with an opportunity for a tangible experience in developing modules. A second purpose, which evolved as the minicourse proceeded and the module-makers began to wrestle with modules, was the exploration of the intent of modules—how to use modules and why use them.

The keynote speaker, Dr. John L. Southin of McGill University, launched the minicourse in fine style with a description of his course, Biology and Social Change. The outstanding attributes of this course are that students have a great deal of flexibility in choosing which of the many modules they will work on and which of the various ways they will complete them. The course is offered jointly by McGill and Sir George Williams College and is open to all students regardless of college level. A large contingent of resource people from both colleges and the community provide counsel and facilities for the students. As a result there is much opportunity for interaction among students and advisors. A "drop-in center" provides a location for those involved in the course to meet and engage in informal dialogue. In fact, interpersonal involvement seems to be the foundation of the course. One example was the sequence of narrated slides prepared by the students for Dr. Southin to present at the minicourse. (The course is described in greater detail in the forthcoming CUEBS Publication on Modules—see announcement below.)

The remainder of the first session was devoted to a description of how audio-visual equipment fits into the development of modularized instruction, presented by Mrs. Gloria Terwilliger, Director of the Learning Resources Center at the host institution. It was followed by a "brainstorming session" in which participants were asked to generate topics for modules, objectives of modules, and the materials and activities desirable to accomplish one of the objectives of a module.

On Friday afternoon and Saturday morning, participants met in small working groups of about 15 people to prepare modules. In most cases, people worked in groups of three or four, although there was much variation in how each working group proceeded with the assigned task. Serving as group leaders were John Busser of BIAC/AIBS, John Thornton of CUEBS, John Sasscer of Northern Virginia Community College, and myself. Each group prepared a 15-minute presentation for the final session of the conference. These presentations ranged from a module on making modules, through a variety of skill and concept-oriented modules, to one which dealt with attitudes about LSD and another which focused on decision-making about optimum world population.

In a narrated slide presentation, Mr. Sasscer described the biology program at the host institution. As he emphasized faculty-student involvement, it was only appropriate that some of the most involved students were on hand to discuss their investigative laboratory projects with participants. The point was made that modules which teach particular laboratory skills are most appropriate in investigative laboratories because each student may learn the specific techniques he needs to carry out the investigation he has chosen.

The light touch was provided by Dr. Donald Perrin of the University of Maryland in his presentation of a module on mixing a martini.

The culminating event was a multi-media module put together and presented under the direction of Lary Davis of CUEBS. Multiple visual images, lights, and sounds were used to dramatize biological organization in an event that our students would undoubtedly refer to as a "happening." Dr. Elwood Ehrle of OBE closed the session with the message that, having shared a variety of modularized experiences including the multi-media happening. "We've seen it and been part of it, let's go home and *do* it!"

The minicourse really had two purposes: the making of modules and the use of modules. In the planning of the minicourse, in the editing of the publication on modules, in fact, in the very act of getting involved in the module project at CUEBS, my stated purpose was to insure that those who use modules use them to humanize the learning experiences of their students rather than to dehumanize them.

The grave danger in the use of modules is that, because they can be designed for individualized and independent study, modules might lead not to more but to less student-teacher interaction than now exists. This would indeed be a tragedy. The beauty of modules is that, once prepared, they free the teacher from mundane and repetitious preparations and presentations. He is free to guide his students to modules appropriate to their needs. He can then spend much of his time communicating with his students, convincing them that he cares about them as individuals, needling them into learning to ask significant questions, and encouraging them to express diverse and original responses. Students need a *lot* of convincing if they are to believe that their instructors really care about them. They need a *lot* of prodding to get them to ask questions. After all, they have spent most of their lives *answering* questions, in spite of the fact that most of man's progress has been made by individuals asking the right questions. Students need encouragement in order to express creative responses. Most of them are so conditioned to seek the one right answer that they are driven "out of their gourds" when an instructor tries to convince them that he is looking for all the plausible, tentative responses they can provide. (These concerns are developed more fully in the articles, "Mortar for the Bricks" and "Where There is No Vision" in the Module publication.)

In reading the drafts of modules prepared by participants in the conference, I discovered that there was considerable spontaneity and creativity in these modules. The qualities of asking relevant questions and supplying original responses were vividly displayed. Could it be that since the participants were neither working for a grade nor laboring under the assumption that there was one "right way" to prepare a module, they came up with a delightful array of approaches to modules and some very penetrating questions about the use of modules?

In reflecting on the mood of the conference, I detected an aura of frustration about the first working session. Not knowing what topic to select in order to develop a module, not knowing the other members of the group with whom they were working, and not having a "feel" for what constitutes a module led to a feeling of frustration by the end of the first working session. In the future, we will consider providing topics, clearly defined instructional objectives related to these topics, and specific instructions on how to go about preparing a module. This might be done at the risk of defining the situation so clearly and with so many constraints that all participants would feel pressured to come up with all the right answers. They might fail to do the more important things, i.e., formulate a variety of approaches, ask relevant questions, and supply original responses.

In order to get into the minicourse without destroying the possibility of creative responses, participants might be asked to look at a course they are currently teaching and ask themselves some questions: Where is your course ineffective? Why? Would modules help? Would modules hinder? After participants have recognized the problem areas that are susceptible to modular treatment, then the minicourse could proceed on the basis that participants had discovered the need to know. They need to explore possibilities and define the intent of a module—how they would use it and why. If the philosophy that "students learn what they need to know when they need to know it" is viable, then students of the minicourse will learn rapidly about making the particular modules they need to serve the purposes they have defined.

This commentary about what we would do differently might leave the reader with the notion that the minicourse was a "flop." Worse yet, it might leave the participants who read this article with the feeling that they should have been disappointed with the minicourse. Yet the spontaneous comments of those who attended indicate that most felt the experience was worthwhile. Although there were some frustrations along the way, there was much enthusiasm for giving modules a try. The mood of participants as they returned to their home campuses could be described as one of "creative insecurity"—a mood most conducive to productive efforts.

DOUBLE-SCREEN LECTURE TECHNIQUE

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For the past 3 years, I have used a double-screen lecture technique that is both effective in developing concepts and in maintaining student interest. Although not a new technique, it is rarely employed by teachers (Salmons, 1961).

Babcock Auditorium of the Hollins College science building is equipped with an 8 ft. x 16 ft. rear-projection screen, in back of which are two Kodak Carousel slide projectors. Each machine projects on one-half of the screen. The lecturer's left hand controls the left projector; his right, the right projector. In this manner either one or both projectors can be advanced at will. The manipulation of two machines looks complicated, but in fact, with a little practice, the operation becomes automatic.

Why project two pictures? Before I answer this question, let us consider the advantages and disadvantages of the single-slide presentation and the chalk talk. It is easy to develop an idea on a chalk-board because each image is retained on the board unless, of course, it is erased. Continuity of thought is maintained because the whole story is on the board. The lecturer using slides, on the other hand, has a real problem when he tries to maintain continuity—he must rely on the class's ability to remember past images; and as we all know, this is often impossible. The slide user does, however, have other advantages—his illustrations are clear and accurate (at least they should be), and he can command their appearance at the touch of a button.

The double-screen technique provides the lecturer and class with the advantages of both teaching methods. This technique: (1) gives the lecturer the capability to make comparisons, i.e., between a diagram and a photomicrograph; (2) enables him to maintain orientation by projecting a low-power photomicrograph of an object on the left screen, and then projecting high-power photomicrographs of portions of the object on the right screen; (3) allows him to set up an experiment on the left screen and show the results on the right; (4) enables him to project a pattern of events (steps) on the left screen and keep these in place while each individual event is projected one at a time on the right; and (5) permits forging strong associations, i.e., between a man's name and an experiment.

To see how this technique works, take a slide sequence that you have lectured from in the past and organize it as a double-screen presentation. If you use a sorting board to arrange the slides, you will quickly grasp the logic of the system.

The system is not without its pitfalls. A student cannot possibly take adequate notes during a double-screen presentation. At Hollins, we projection-print key black and white negatives on Kodagraph paper and then make duplicator spirit masters on a Thermofax machine. The masters are run on a standard fluid duplicator machine with the result that each student has a set of the key illustrations. We consider key illustrations to include important diagrams, biochemical pathways, genetics problems, etc. As an example, the entire biochemical pathway is projected on the left screen, while the individual steps are projected on the right. Before the lecture begins, duplicated sheets of the entire pathway are given to the students.

When I lecture in this manner, my full attention is given to the discussion of the pathway, not its writing. The student devotes her full attention to understanding the discussion, not note taking. Fewer carbons wind up having five bonds this way. I can remember, as a student, frantically copying from a blackboard, usually three steps behind the professor, hoping the professor wouldn't erase the parts I hadn't copied. Our students don't operate under that kind of anxiety. All they need do is listen and understand, and perhaps take a few notes.

The double-screen lecture is well received, and is fun, but exhausting, to deliver. I hope the above comments will spark some of you to attempt the technique.

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A Promising Visual Technique

Occasionally one of the countless gadgeteers among academic biologists makes a real breakthrough on the instructional front that leaves us all (manufacturers included) asking, "Now why didn't I think of that?" William Klein, botanist at Colorado State University, may have done just that with a promising new visual technique employing two Kodak carousel projectors coupled with a Spindler-Sauppe Dynamic Dissolve unit. Successive 2 x 2 color slides are taken "in registration," which means that closely similar images are placed in identical positions on the two or more transparencies. The transparencies are then dissolved one into the other rather than having the distracting blackout between slides which one sees in conventional projection systems. Thus, a whole flower in lateral view can be replaced by the same flower in longitudinal section, and a third slide, exactly outlining and naming the parts of the flower, can replace that. The advantages of this particular system arise from the ability of the projectionist to control the rate of dissolve and to produce special visual effects. Slides can be rapidly dissolved (cut) or they can be dissolved at extremely slow dissolve rates (lapped). Through the lap dissolve capability, images can be superimposed in ways to facilitate comparison and heighten the visual impact of the presentation.

A McLuhanite at heart, Klein has devised a remarkable range of applications for the technique and has several lectures available for demonstration. The narrative in these presentations becomes a staccato of words and phrases, offering verbal reinforcement to the flow of visual information. Klein claims that he is working to change the concept of "visual aids" wherein visuals are considered only aids to the spoken or written work. He feels that in order to take advantage of the revolution which has occurred in communication, teachers must think in terms of "verbal" rather than "visual aids." The technique also provides the instructor with opportunities to develop materials and work out problems presented by the electronic media.

In addition to the dissolve system of presenting information, Bill is also working on some automated audio-visual supplements to traditional botany laboratories, particularly in the area of systematic botany. The visual approach in the supplements are designed to expand considerably the student's range of experience with plants and to heighten his interest in botany.

Bill will be demonstrating the botanical applications of Dynamic Dissolve at the annual AIBS summer meeting, August 29 through September 3, 1971, in Fort Collins. If you are there, don't miss the chance to see this unusually promising visual technique.

Dana L. Abell
CUEBS Senior Staff Biologist

Computerized Class Record-Keeping

One of the more prosaic innovations in undergraduate biology in recent years has been the development of computerized systems to maintain records of student performance in very large introductory biology classes. True, the undergraduate becomes a mere number in such a system, with the system thus striking yet another blow for the depersonalization of education. However, it should be no problem at all to convince people that the advantages can be significant. For example, don't grade reports on examinations within the same day represent something of a gain over the 3- to 5-week wait many students have to face in getting feedback on their performance? Also doesn't the knowledge that item analyses are being run on practically every examination and quiz question, with an eye toward steady improvement of the evaluation and feed-back process, add at least a little feeling of confidence to the "depersonalized" wielders of punch-out cards? And, doesn't the chance that one gains to shift staff time from mere record-keeping to student contact constitute a very real advantage?

Harris (Bud) Linder, the University of Maryland Zoology Department at College Park, and Charles Lytle, the Institute of Biological Sciences at North Carolina State University in Raleigh, think so. Both have indicated a willingness to share some of their experiences along this line with other slaves of the massive grade book, both past and present. Nothing was said in either case about sharing computer programs but perhaps there is at least ground for discussion.

Dana L. Abell
CUEBS Senior Staff Biologist

THE PHYSIOLOGY TEACHER

By now you should have received a copy of THE PHYSIOLOGY TEACHER, a new publication of the American Physiological Society, under the editorship of Dr. Nancy Milburn. CUEBS is indeed pleased to welcome this newsletter and congratulates the American Physiological Society on its effort to assist college biology teachers in both elementary and advanced courses.

CUEBS also takes this opportunity to commend the American Physiological Society on the appointment of Dr. Orr E. Reynolds as its Education Officer, with a Washington office (9650 Rockville Pike, Bethesda, Md. 20014.)

Viewpoints!

Mathematics for Biologists— A Battle Plan

Dana L. Abell
CUEBS Senior Staff Biologist

The long-expected publication last fall of "Recommendations for the Undergraduate Mathematics Programs for Students in the Life Sciences"[1] by the Committee on the Undergraduate Program in Mathmatics seems certain to stimulate thought on the problem of working adequate mathematics into undergraduate biology curricula. The report, which will presumably be known as "the pale blue-and-white book," after its black-and-white and blue-and-white predecessors,[2] recommends that students in the life sciences (biology, medicine, agriculture and renewable resources) be required to take a minimum of four semesters of college-level mathematics—two of calculus (including some multivariate analysis), and one each of linear algebra and probability (with statistics). The recommendation applies to all degree candidates from the bachelor's level to the Ph.D. The report also recommends "that every undergraduate have some contact with an automatic digital computer, and that this contact begin as early as possible in his program of study." Typically, this will be offered outside a mathematics department and will take the form of a discrete course.

The panel which prepared the report is a direct descendant of the group which developed the impressive collection of mathematical models that was published with NIH support in 1967 by CUPM.[3] Therefore it is no surprise to find them pleading a convincing case here for a life sciences version of the black-and-white report's applied mathematics course (Mathematics 10) which would be essentially model-building. If both computation and model-building must take the form of separate courses, the report has to be read as recommending six semesters of mathematics for students in the life sciences.

The panel's substantive recommendations do make sense. The quicker overview of calculus, to include multiple variables and linear algebra in the program, is clearly appropriate for those who must understand and deal with complex biological phenomena. But in recommending six semesters of mathematics and computation, the Panel has simply reemphasized a dilemma of long-standing, namely, how does one find time, with all that math (and chemistry, and physics, and what have you) to present sufficient biology for a major program?

Answers, now that the mathematicians have once again had their say, must clearly come from life scientists who have the sort of mathematical savvy that we hope our students can gain. Perhaps one answer may lie in the gap that exists between being mathematically literate and being capable of exercising mathematical initiative. The means may have to be found in a large-scale shift to individualized instruction in mathematics, but certainly part of the solution lies in a wider acceptance by teachers of mathematics of intuitive explanations as opposed to rigorous proofs.

But we cannot hope for progress by attempting to *tell* the mathematician what he must do. Understandably, mathematicians as a group show little respect for either the concept of this lower level of mathematical awareness that we outsiders call "literacy" or for the idea of using mathematics in a cookbook fashion. Nor have they responded enthusiastically to the suggestion, also largely from outsiders, that individualized instruction (in the self-directed continuous progress modes) might be especially appropriate to mathematics.

We may be able to apply a little operant conditioning, however, and as outsiders, respond favorably to suggestions that mathematicians themselves have offered and discussed: (1) let us express satisfaction with the now nearly universal practice of putting calculus at the introductory college level and of dealing with differential and integral calculus more or less simultaneously; (2) applaud the suggestion that multivariate analysis can profitably be dealt with in part of a second semester of calculus; and (3) agree that linear algebra does need to be brought down within reach of the life science major.

Then we might note that there are still a number of important mathematical concepts that the life scientist may need to grasp—perhaps not only to generate analyses of his own as to listen intelligently to discussions presented by his more mathematically able colleagues and to ask intelligent questions of cooperating mathematicians. The question then arises, how can all of this be covered within the limited time—say two or three semesters—that a life science major can spend in mathematics? Our conditioning sequence continues: (4) let's agree that "general mathematics" smacks too much of the survey course which satisfies no one but a few loose-hanging students and archaic registrars, both bent only on tallying credits for distributive requirements; (5) ask to what extent courses in "finite mathematics" represent progress over the old math appreciation courses and whether some concepts from symbolic logic, set theory, or the ideas of Markov chains and matrices aren't rather well handled there, albeit in abbreviated intuitive form. Now we move quickly in for the kill, noting that the pale-and-blue-and-white panel's direct antecedent said something along these lines itself when it looked, in preparing the blue-and-white report, at the undergraduate mathematics program not as a series of courses but as a sequence of *ideas* arranged without the

[1] Committee on the Undergraduate Program in Mathematics, 1970. Recommendations for Undergraduate Mathematics Programs for Students in the Life Sciences: An Interm Report. Berkeley, Calif.

[2] ———. 1965. A General Curriculum in Mathematics for Colleges. Berkeley. ("The black-and-white report.")

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[3] Thrall, R. M., J. A. Mortimer, K. R. Rebman, and R. F. Baum. 1967. Some Mathematical Modules in Biology. CUPM, Berkeley. (Out of print)

hindrance of course titles into a rough 2-year study plan. Now we ask, "Well, have some of these topics been satisfactorily presented in programmed instruction booklets?" or, "Does the audio-tutorial program in finite mathematics at X University have anything at all to its credit in these areas?"

Why, actually, *does* mathematics have to come just in course-sized packages, bearing names that date, sometimes, all the way back to Leibnitz and Descartes? Chunks of mathematical subject matter have in fact been shifted around from course to course in recent years: e.g., the scattered pieces of analytic geometry, also set theory. Is there hope that the programmatic view that was offered by the blue-and-white panel, which was set aside by the newer life sciences panel in deference to the General Curriculum's overbearing concentration upon courses as such, may eventually prevail?

Perhaps the hope lies in bringing mathematics instructors into direct contact with biology students on a task force basis as these students grope with biological problems that require mathematical solutions. This, in fact, might be a major contribution that some of the experimental colleges such as Hampshire and Evergreen State or Governors State University (in Massachusetts, Washington, and Illinois, respectively) could make, since curricula at each of these colleges will apparently be developing through projects in connection with environmental problems. In such a situation, the mathematician must prove his worth on a bit-wise basis, and once proven there in connection with specific problems, what could be better than to export the experience in a modestly generalized fashion to institutions seeking to reshape their more traditional practices to fit current needs?

The beauty of this is that probability and statistics, modeling, and computer applications are woven quite naturally into the fabric of the project experience, supplementing the chunks of purer mathematics that are inserted into the problem—oriented programs and cuting down the apparent load of mathematical instruction needed by biology majors. An added benefit might well be a biologist who no longer pulls down figurative blinds over his consciousness and flips that "off" switch the instant mathematical notation appears. Less beautiful for the mathematician is the unpleasant truth that mathematical concepts will often have to be developed intuitively rather than through fully developed, rigorous proof, which not only gives mathematics much of its strength but is a major source of its own form of beauty.

In any event, we have much to learn about making these six semesters of math fit into our two or three-semester mold. Perhaps these way-out experimenters will be the ones who can tell us most for awhile. If they can do nothing more than this before they become beset with their own traditions, they will have served society well.

In sum, the new report does represent progress in that it identifies choices within the strict course-block framework established by the 1965 "General Curriculum"; but it illustrates, through contrast with the 1964 Blue-and-White report, the very great advantage of looking at a department's offerings in terms of predictable student needs and of the programs that can be devised to meet them. This was the major lesson—now largely forgotten—of the CUEBS core curriculum study. It was a lesson that was apparently lost on CUPM. In this respect, the pale-blue-and-white report represents, for biologists, a compromise with tradition that came before the revolution had even started. Is not a new attempt by biologists to cross this difficult frontier, with the aim of bringing long overdue integration of some undergraduate biology with some undergraduate mathematics, called for now?

PUBLICATION ANNOUNCEMENT

Available Mid-April

Publication 31—The Use of Modules in College Biology Teaching

Available Early May

Guidelines and Suggested Titles for Library Holdings in Undergraduate Libraries

This is a revision of Publication 22, Basic Library List for the Biological Sciences

19

AVAILABLE CUEBS PUBLICATIONS

Free upon request from CUEBS, 3900 Wisconsin Ave., N.W., Washington, D. C. 20016

PUBLICATIONS

7. * The consultant bureau. Revised, August, 1967 (for those interested in obtaining curriculum consultant service).
16. * Guidelines for planning biological facilities. August, 1966 (materials including description of facilities consultant service).
19. Biology for the non-major. October, 1967.
20. * Testing and evaluation in the biological sciences. November, 1967,
22. Basic library list for the biological sciences. March, 1969.
23. Teaching and research. May, 1969.
24. Preservice preparation of college biology teachers: a search for a better way. November, 1970.
25. The pre-service preparation of secondary school biology teachers. June, 1969.
26. Biology in the two-year college. April, 1969.
27. Biological prerequisites for education in the health sciences. June, 1969.
28. Investigative laboratory programs in biology. December, 1969.
29. Funds for undergraduate biology departments . . . and how to find them. May, 1970.
30. Role playing and teacher education. March, 1971.
31. The use of modules in college biology teaching. April, 1971.
32. Guidelines and suggested titles for library holdings in undergraduate biology. May, 1971.

* Request by individual letter, to AIBS Office of Biological Education, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016.

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2. A working conference on source material in physics-biology-agriculture and natural resources. June 1970 .

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